

Thesis/
Reports
FIEDLER,
C. E.

ECOSYSTEM MANAGEMENT STUDY
LICK CREEK RESEARCH/DEMONSTRATION AREA
SUMMARY REPORT - FIVE-YEAR RESULTS

Research Joint Venture Agreement - RJVA

26 June, 1998

Carl Fiedler

School of Forestry

University of Montana

Missoula, MT 59812

INTRODUCTION

Prior to the 1900's, lower and mid-elevation slopes in the Bitterroot Valley were occupied by ponderosa pine (*Pinus ponderosa* Laws.) dominated forests with relatively open understories (Leiberg 1899; Gruell et al. 1982). The structure, density, and species composition of these forests were strongly influenced by surface fires that occurred at 3- to 30-year intervals (Arno 1976). Frequent, low-intensity underburning on these and similar sites throughout the Inland Northwest favored the regeneration of ponderosa pine in small openings created by scattered wind-, insect-, or lightning-caused mortality (Weaver 1947). Stands that developed under the pre-1900 fire regime were primarily ponderosa pine in composition and uneven-aged in structure (Meyer 1934; Weaver 1943; Gruell et al. 1982).

Beginning in the early 1900's, logging and fire suppression began to alter both the ecological processes and open appearance that typified low- to mid-elevation forests in the Bitterroot Valley. Logging preferentially removed large-diameter ponderosa pine (Leiberg 1899), and fire exclusion favored regeneration, particularly of moderately shade-tolerant Douglas-fir.

Consequently, the forest conditions that exist in the Bitterroot today are fundamentally different -- in terms of species composition, density, structure, and health -- than those that prevailed a century ago (Gruell et al. 1982). Regeneration of Douglas-fir is increasing. Stand densities are increasing, especially in the understory component. Stand structure and species composition are changing from ponderosa pine overstory dominance to an emerging Douglas-fir understory. Stand health is also deteriorating, with western spruce budworm (*Choristoneura occidentalis* Freeman) and dwarf mistletoe (*Arceuthobium douglasii* Engelm.) increasingly prevalent in the Douglas-fir component of storied stands (Gruell et al. 1982). Maladies in ponderosa pine that are increasing in severity include suppression in the understory component and mountain pine beetle (*Dendroctonus* spp.) activity in the overstory, both of which are due to overstocking and concomitant low vigor.

Recognizing the fundamental changes that have been occurring in the nation's forests since the arrival of European-Americans, the Forest Service now emphasizes ecologically-based forest management aimed at reestablishing or sustaining ecosystem function and productivity, and improving forest health.

This study is part of a research/demonstration project initiated in 1991 in the Lick Creek drainage of the Bitterroot National Forest. The overall project is aimed at developing sustainable, ponderosa pine dominated forests from three different existing stand conditions. This study "Evaluation of

Uneven-Aged Silviculture and Underburning for Managing Ponderosa Pine/Douglas-fir Forests in Montana" is being conducted in conjunction with two companion studies: 1) "Evaluation of Shelterwood Cutting and Prescribed Burning for Enhancing Multi-Resource Values of Second-Growth Ponderosa Pine Stands", conducted by Steve Arno, and 2) "The Impact of Different Fire Treatments on Survival and Growth of Thinned, Immature Ponderosa Pine" conducted by Mick Harrington.

The USFS's New Perspectives' program (Salwasser 1990) provided the impetus for the current research and demonstration activities at Lick Creek. Ideas for the Lick Creek project were developed and discussed in meetings with Bitterroot National Forest, Darby Ranger District, and Rocky Mountain (formerly Intermountain) Research Station personnel. Work on this particular study started in the spring of 1991 with several reconnaissance trips to the Lick Creek area with the previously-mentioned cooperators. These trips were used to discuss research needs related to New Perspectives (sustainable ecosystem) management, plan research activities, and find suitable stand conditions for conducting the appropriate research.

A reconnaissance of the Lick Creek area identified a stand with characteristics (predominantly ponderosa pine, uneven-aged stand structure) appropriate for the objective of this study, which is to evaluate the effectiveness of a modified individual tree selection method and prescribed underburning for maintaining

ponderosa pine in its historic role as a dominant seral species in relatively open, uneven-aged stand structures.

A more detailed examination of the approximately 100-acre study site yielded three reasonably homogeneous, approximately 10-acre parcels to be used in the study. Each of the three parcels is being used as an experimental block, since one parcel is above the main contour road, one below the road, and a third about a quarter mile west of the other two blocks. Each block was subdivided into three 2.4-acre (4-ch x 6-ch) treatment units, and one replicate of each treatment randomly assigned to the three units.

During July and August of 1991, a 100 percent inventory (tree tally) was conducted by one-inch diameter class, condition class (crop, acceptable, unacceptable), and species within each 2.4-acre treatment unit. The one-inch diameter tally for each unit was subsequently collapsed into broader four-inch classes to facilitate marking the respective prescriptions.

In September 1991, leave trees were marked with ribbon in the six units (two units per block) that had been randomly assigned a cutting treatment. Harvest cutting occurred in the late summer and fall of 1992.

The overall objective of the Lick Creek project is to compare the effectiveness of alternative silvicultural treatments for developing approximate pre-1900 conditions in terms of species composition, stand structure, and forest floor/down woody material loadings. More specifically, this means reestablishing

and perpetuating ponderosa pine as the predominant species and keeping forest-floor materials at relatively low levels in these historically fire-dominated ecosystems. To accomplish this, stands must be open enough to allow ponderosa pine -- a shade intolerant species -- to regenerate and ultimately develop into large diameter trees. Instead, the suite of conditions that has prevailed since the early 1900s -- increasing stand density and infrequent surface fires -- has favored regeneration of shade-tolerant Douglas-fir. A major problem associated with this change is that dense fir understories provide surface fires a means of torching into the mid- and upper canopy. Consequently, the long-term goal of perpetuating stands in place, developing large trees, and increasing the composition of ponderosa pine depends upon periodically reducing stand densities and obtaining adequate pine regeneration following each harvest entry. Determining the post-harvest density levels under which natural regeneration of this intolerant species can occur, and under which juvenile growth is rapid enough to maintain tree vigor, is critical to the successful application of uneven-aged systems in ponderosa pine/Douglas-fir forests.

Virtually all prior studies of competition have been conducted in even-aged stands (Noone and Bell 1980). Yet, determination of the effects of competition on growth is considerably more complex, and perhaps even more critical, in multi-storied uneven-aged stands. Competitive effects on the growth of smaller trees is especially important on the dry to

moderate Douglas-fir habitat types where uneven-aged systems are most appropriate (Fiedler et al. 1988), because shade-intolerant ponderosa pine dominated these sites when natural (pre-1900) ecological processes prevailed. Dense conditions can also result in suppression-caused death of smaller trees, and death of larger trees from a variety of stressors.

The general, long-term objective of this study, then, is to determine the efficacy of a modified individual tree selection approach for sustaining healthy, uneven-aged ponderosa pine forests (featuring some large, old trees) into perpetuity, while producing substantial volumes of wood products on a regular basis and in a visually appealing way.

Specific objectives of this study are:

- 1) To compare diameter, height, basal area, cubic foot, and board foot increment by diameter class and treatment.
- 2) To compare mortality over time by cause (fire, bark beetles, and other), diameter class, and treatment.

STUDY AREA

The Lick Creek Research Demonstration Area is located just north of Lake Como in the Bitterroot Valley of western Montana. The study site is located mid-slope on a southwest aspect between 4500 and 4700 ft elevation. The study site is occupied by an uneven-aged, predominantly ponderosa pine stand, with lesser amounts of Douglas-fir. Slopes range from five to 30 percent. The primary habitat type is PSME/CARU h.t., PIPO phase (Pfister et al. 1977).

DESIGN

Three treatment combinations were evaluated in this study:

- 1) modified individual tree selection cutting (reserve basal area = 50 ft²/ac) with prescribed broadcast burn (cut/burn treatment),
- 2) modified individual tree selection cutting (reserve basal area = 50 ft²/ac) without burning (cut/no-burn treatment), and 3) no cutting or burning (existing basal area 100 ft²/ac), hereafter referred to as the control treatment. A randomized block design was used to evaluate the effect of these treatments on diameter, height, basal area, cubic foot, and board foot growth. Mortality is also being evaluated in this framework.

Three reasonably homogeneous landscape parcels (blocks) were delineated -- each large enough to accommodate one replication of each of the three treatments. Each block was subdivided into three treatment units, and one replicate of each treatment was then randomly assigned to each of the three units.

The prescription for each of the three treatments is detailed below:

Cut/burn

Reserve BA = 50.0 ft²/ac

q = 1.2 (4-in classes)

Maximum DBH = 20 in

Cut cycle = 20-30 years

Species: PP>DF

Prescribed underburn at each harvest entry

One or two trees per acre ≥ 24 -in DBH, and preferably with poor form/vigor, will be left per acre for snag recruitment. The basal area of these trees will not be included in the regulated stand prescription. Total residual basal area (50 ft^2/ac regulated + snag recruits) will not exceed 60 ft^2/ac .

Cut/no-burn

Reserve BA = 50.0 ft^2/ac

q = 1.2 (4-in classes)

Maximum DBH = 20 in

Cut cycle = 20-30 years

Species: PP>DF

No prescribed burn

One or two trees per acre ≥ 24 -in DBH, and preferably with poor form/vigor, will be left per acre for snag recruitment. The basal area of these trees will not be included in the regulated stand prescription. Total residual basal area (50 sq ft regulated + snag recruits) will not exceed 60 sq ft/ac .

Control

Reserve BA = 100.0 ft^2/ac (existing stand)

q = Existing

Maximum DBH = Existing

Cut cycle = No cutting in foreseeable future

No prescribed burn

METHODS

Treatment units are 2.4 ac (1 ha) in size (6 ch x 4 ch), with a similarly treated buffer 0.5-ch in width. Each of the nine units was leave-tree marked to the reserve density target (50 ft^2/ac). All leave trees ≥ 1.6 -in. in diameter at breast

height (dbh) were permanently numbered with aluminum tags and measured for diameter.

The following trees were measured for height and crown length: all trees ≤ 5 " dbh, a 20 percent stratified random subsample of trees in the 6-in. through 16-in. diameter classes, and all trees ≥ 18 -in. in diameter. Each of the treatments (cut/burn, cut/no-burn, control) was then randomly assigned once within each of the three blocks. This approach allows determination of the effects of competition on growth, since among treatment comparisons are based on trees that were of similar size, vigor, and spacing at the beginning of the study. Each tagged tree was also rated for vigor using Keen's (1943) classification.

Response variables either measured or calculated in this study include diameter, height, basal area, cubic foot volume, and board foot volume. Additional factors of interest include overall mortality, and important specific causes of mortality such as fire damage and bark beetles.

RESULTS AND DISCUSSION

Growth Increment

Diameter: The modified individual tree selection cutting prescribed in this study had a substantial positive effect on diameter growth during the first five years of the study (Figure 1). For example, the mean diameter increments of trees in the 2-in. to 8-in. diameter classes in the cut/no-burn treatment varied from about 70 to 225 percent greater than that of the

corresponding diameter classes in the control. Likewise, trees in the 10-in. to 18-in. classes outgrew their counterparts in the control by a margin of 38 to 108 percent. However, no clear pattern was discernible at the large end of the diameter distribution, where trees in the 20-in. and 24-in. classes in the control grew somewhat faster than comparable trees in the cut/no-burn treatment. Conversely, trees in the 22-in., 26-in., and ≥ 28 -in. diameter classes in the cut/no-burn treatment grew modestly faster than similar-sized trees in the control.

Diameter increment averaged 0.18 in. per year for trees up to 20-in. in diameter in the cut/no burn treatment, then decreased sharply in trees ≥ 20 -in. dbh. In contrast, trees in the cut/burn and control treatments averaged only about 0.12-in. and 0.10-in. increment per year before growth dropped off sharply in the ≥ 16 -in. and ≥ 22 -in. diameter classes, respectively.

The strong positive effects of density reduction on diameter growth documented in the cut/no-burn treatment were generally offset by the negative impacts of burning in the cut/burn treatment. The apparently deleterious effect of burning on diameter growth for the first five years following treatment is likely due to crown scorch and possible damage to roots near the surface. A minor number of trees may also have suffered cambial damage at the root collar, or on the lower portion of the bole. The dampening effect of fire on diameter growth was particularly noticeable in the larger diameter classes. For example, diameter increment was greater in the control than the cut/burn treatment

for all trees ≥ 16 -in. diameter, with the lone exception of trees in the 26-in. diameter class. The apparently greater impact of fire damage on growth of large trees than small ones seems counterintuitive. However, the effects of moderate or greater fire damage to smaller trees may be to kill them, whereas larger trees may survive similar levels of damage, but suffer significant impacts on growth.

Height: Height increment patterns were nearly identical for the cut/no burn and control treatments (Figure 2). Annual increment varied between 0.6 and 0.8 ft, and averaged 0.7 ft in both treatments. Height increment was noticeably lower in the cut/burn treatment, particularly for trees < 16 -in. dbh, which averaged < 0.5 ft growth per year. Height growth of the largest trees (≥ 28 in.) also appeared to be negatively affected by burning, averaging only 0.3 ft per year, although only two trees were present in this class for comparison (Figure 2).

Height increment varied less among treatments than any of the other response variables measured or calculated in this study. For example, height increments for trees in the cut/no-burn and control treatments were virtually identical across all diameter classes. This result is consistent with the widely held view that height growth is relatively unaffected by density across a fairly wide range of densities. The underlying reason may be that height growth occurs in a relatively short period in the spring and early summer -- a period when moisture is

relatively plentiful, and therefore available, to trees across a wide range of densities.

In contrast, height increments were greater in the control than in the cut/burn treatment for every diameter class from 2-in. through 18-in. This result is in contrast with the previous comparison of diameter increments between these two treatments, where the negative impact of fire on growth was only observed in the larger trees (i.e. ≥ 16 -in.). This apparent anomaly may be due to the fact that height growth occurs earlier in the year than diameter growth. In this case, smaller trees generally suffer greater relative damage from fire than large trees -- damage which could impede height growth during a time when moisture is generally available, even to small trees in a relatively poor competitive position. In contrast, diameter growth of larger trees may be impeded more later in the growing season, a period when they typically dominate limited growth resources, particularly moisture.

Basal Area: Periodic annual basal area increment was also highest in the cut/no burn treatment, averaging 0.024 ft²/per tree for trees of merchantable size (>6 -in. diameter; Figure 3). Comparable basal area increments for the cut/burn and control treatments were 0.016 ft² and 0.018 ft² per tree, respectively.

Annual basal increment per square foot of basal area was highest in virtually all diameter classes for the cut/no burn treatment, but showed a similar pattern in all three treatments (Figure 4). This ratio, which is sometimes used as a measure of

growth efficiency, was highest in the 2-in. diameter class, dropped sharply in the 4-in. and 6-in. classes, and then declined very gradually with increasing diameter through the remainder of the distribution in all three treatments. Trees in the 22-in. and larger diameter classes in the cut/burn treatment had noticeably lower basal area increment per square foot of basal area than did similar sized trees in the cut/no burn and control treatments, indicating that the negative effects of fire damage on growth were greatest in the large-tree portion of the diameter distribution.

Comparing basal area growth efficiency among treatments showed that trees in the cut/no-burn treatment were most efficient. Basal area increment per square foot of basal area was 0.0217 in this treatment. Corresponding growth efficiencies in the cut/burn and control treatments were 0.144 and 0.154, respectively.

Cubic Foot Volume: In all treatments, periodic annual cubic volume increment per tree increased rapidly with increasing diameter for trees from 2-in. to 14-in. dbh (Figure 5). Cubic volume growth then increased only gradually for trees in the 14-in. through 26-in. diameter range. Cubic volume increment per tree was noticeably higher for the largest trees (≥ 28 in.) in each treatment, particularly the cut/no-burn and control treatments. Again, there appeared to be a deleterious effect of burning on growth in the cut/burn treatment, although results for

this treatment are based on a very small sample of large trees (n=2).

Board Foot Volume: Periodic annual board foot volume increment per tree gradually increased with diameter from the 10-in. class upward in all three treatments (Figure 6). The lone exception was for trees ≥ 28 -in. diameter in the cut/burn treatment, which is likely an anomaly due to the small number of trees (n=2) in this size class. While the trend was the same in all treatments, the cut/no burn treatment generally supported the greatest board foot growth per tree in any given diameter class. In the cut/burn treatment, however, the beneficial effects of density reduction on growth were apparently almost entirely offset by fire damage (Figure 6).

Mortality

All Causes: Total five-year mortality (all causes) varied considerably among treatments, but was highest in the cut/burn treatment (Figure 7). Mortality within the cut/burn treatment was greatest in the 2-in. and 4-in. diameter classes, and then gradually declined with increasing diameter through the 20-in. class. Trees larger than 20-in. suffered no mortality in any treatment, with the exception of trees ≥ 28 -in. diameter in the cut/burn treatment, where two of the four trees present died during the five-year period.

No trends were evident in the cut/no-burn treatment because only one tree died during the entire five-year period (Figure 7). Mortality in the control was intermediate to the other two

treatments. Approximately half of the mortality in this treatment was due to beetles, with the remainder due to other causes.

Fire: Mortality due to fire could only be assessed in the cut/burn treatment, since it was the only treatment that received prescribed burning. Fire was the major mortality factor in the 2-in. and 4-in. diameter classes in the cut/burn treatment (Figure 8). Fire-caused mortality remained stable at two to four percent of the trees present in the 6-in. through 16-in. diameter classes. No trees larger than 16-in. in this treatment died due to the effects of fire.

Beetles: Bark beetles (*Dendroctonus* spp.) were an important mortality factor in the cut/burn treatment, accounting for 4 to 12 percent mortality in the 4-in. through 20-in. diameter classes (Figure 9). Beetles also killed two of the four trees present in this treatment that were ≥ 28 -in. in diameter. In contrast, no trees of any size were killed by beetles in the cut/no-burn treatment, and only sporadic mortality due to this factor was observed in the control treatment (Figure 9).

A range of from 10 to 75 percent of the trees present in the cut/no burn treatment were attacked by beetles, depending on diameter class (Figure 10). Overall, 37 percent of the trees in this treatment were attacked by beetles. Attack levels were much lower in the other two treatments, however. Only 10 percent of the trees in the cut/no-burn treatment and 3 percent of the trees in the control were attacked, respectively.

The relatively constant rate of beetle-caused mortality across a wide range of diameters in the cut/burn treatment suggests that trees were generally stressed by burning, and hence attractive targets for beetle activity. In contrast, the sporadic pattern of beetle mortality relative to diameter in the control treatment suggests that scattered pockets (or clumps) of stressed trees of similar size were successfully attacked and killed.

Other: Other mortality causes combined, including such things as animals, weather, logging damage, and suppression, were only a minor mortality factor in all three treatments through the first five years of the study (Figure 11).

Evaluating mortality on an annual basis provides insights that may be obscured when looking at five-year totals only. For example, cumulative annual mortality showed two distinct trends in the cut/burn treatment. Virtually all of the mortality attributed to fire occurred in the first two years of the study (Figure 12). Attrition due to bark beetles, in contrast, continued throughout the first five years of the study, albeit at a somewhat lower level during the last two years (Figure 12).

CONCLUSIONS

Results from the first five years of this study provide positive initial signs that a modified individual tree selection system can be used to sustainably manage ponderosa pine in uneven-aged structures. Substantially higher growth rates across nearly the entire diameter distribution in the cut/no-burn

treatment, coupled with the virtual absence of mortality, indicates the health and vigor of the reserve stand resulting from this treatment. In contrast, the similarity in post-treatment periodic growth rates between the cut/burn and control treatments suggests a considerable dampening effect of burning on growth. There are several reasons why the poor growth performance in the cut/burn treatment should not be interpreted as unsuccessful or undesirable, however, especially at this early juncture. First, while mortality in this treatment was substantial, it had tapered off considerably by year five. Secondly, under the prescription being evaluated, 20 percent more trees are left in each successively smaller 4-in. diameter class as a buffer for anticipated mortality (and to allow some flexibility in leaving the best phenotypes in future entries). Put another way, the moderate mortality documented in the cut/burn treatment, particularly in the 2-in. and 4-in. classes (Figure 8), was essentially offset by the additional trees reserved in the smaller diameter classes. Finally, short-term deleterious effects on individual trees may be more than offset by mid- and long-term beneficial effects at the stand level (e.g. stimulation of undergrowth forage species, hazard reduction, nutrient cycling, killing of small firs, etc.), which are primary objectives of prescribed burning. Furthermore, these objectives of burning likely cannot be achieved without at least some mortality of leave trees, particularly in the smaller diameter classes.

Moderate numbers of vigorous young pine seedlings are present in openings throughout the selection cut units. These are the recruits that are essential for perpetuating this uneven-aged stand into the future. They are also one indicator of a successful treatment.

A much longer period than five years is needed to evaluate the effectiveness of these three treatments in terms of meeting long-term objectives. However, an installation is now in place that provides the basis for making such an evaluation. The treatments being evaluated in this study also serve as examples (or points of departure) for managers to either adopt or modify as needed for current management applications. Finally, this study, in conjunction with the companion shelterwood and thinning studies at Lick Creek, provides forest managers and the general public much-needed visual demonstrations of management options in ponderosa pine forests.

LITERATURE CITED

- Arno, S. F. 1976. The historical role of fire on the Bitterroot National Forest. Res. Pap. INT-187. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Station. 29 p.
- Fiedler, C. E., Becker, R. R., and S. A. Haglund. 1988. Preliminary guidelines for uneven-aged silvicultural prescriptions in ponderosa pine. p. 235-241 In: Symposium proceedings, Ponderosa pine - the species and its management. Washington State Univ. Coop. Ext., Pullman, WA
- Gruell, G. E., Schmidt, W. C., Arno, S. F. and W. J. Reich. 1982. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana - implications for resource management. Gen. Tech. Rep. INT-130. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Station. 42 p.

- Keen, F. P. 1943. Ponderosa pine tree classes redefined. *Journal of Forestry* 41: 249-253.
- Leiberg, J. B. 1899. The Bitterroot Forest Reserve. Washington D.C.: U.S. Geological Survey. 19th Annual Report (1897-1898), Part V: 253-282.
- Meyer, W. H. 1934. Growth in selectively cut ponderosa pine forests of the Pacific Northwest. Tech. Bull. No. 407. Washington, D.C.: U.S. Department of Agriculture. 64 p.
- Noone, C. S. and J. F. Bell. 1980. An evaluation of eight intertree competition indices. Oregon State Univ. For. Research Lab. Res. Note 66. 6p.
- Pfister, R.D., Kovalchik, B.L., Arno, S.F., and R.C. Presby. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Station. 174 p.
- Salwasser, H. 1990. Gaining perspective: Forestry for the future. *Journal of Forestry* 88: 32-38.
- Weaver, H. 1943. Fire as an ecological and silvicultural factor in the ponderosa pine region of the Pacific slope. *Journal of Forestry* 41: 7-14.
- Weaver, H. 1947. Management problems in the ponderosa pine region. *Northwest Science* 21: 160-163.

Figure 1. Periodic annual diameter increment by treatment and diameter class, for the five-year period 1993-1997.

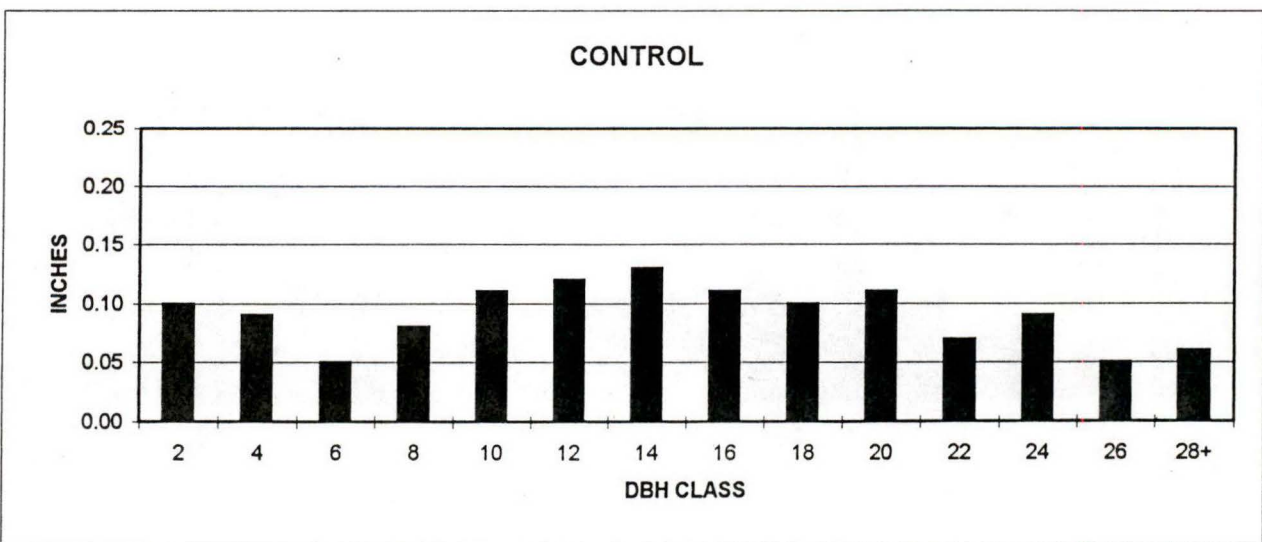
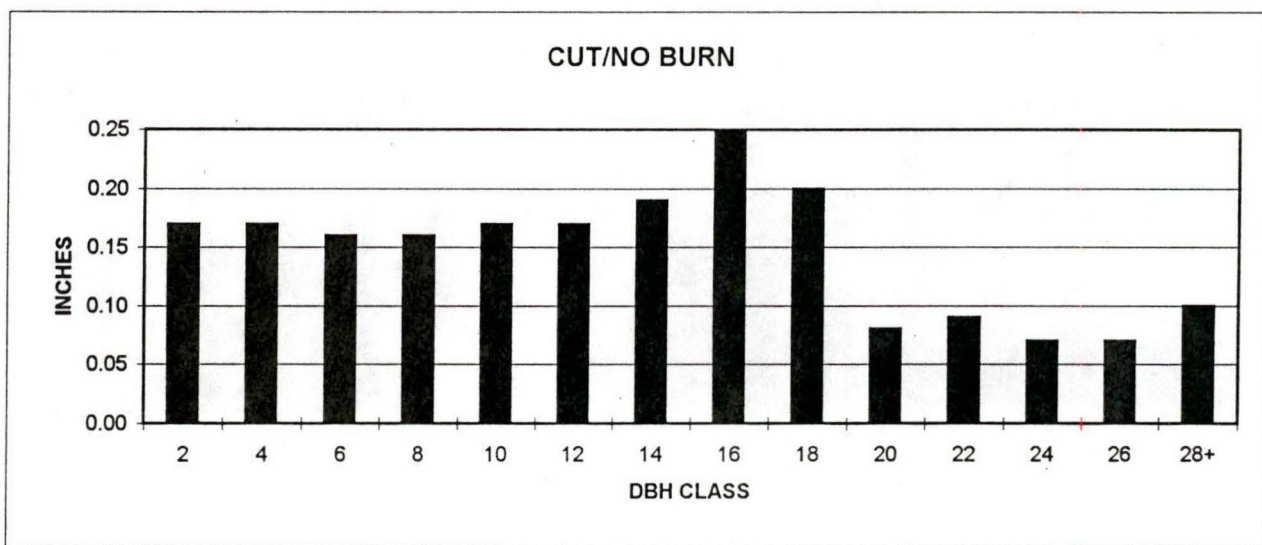
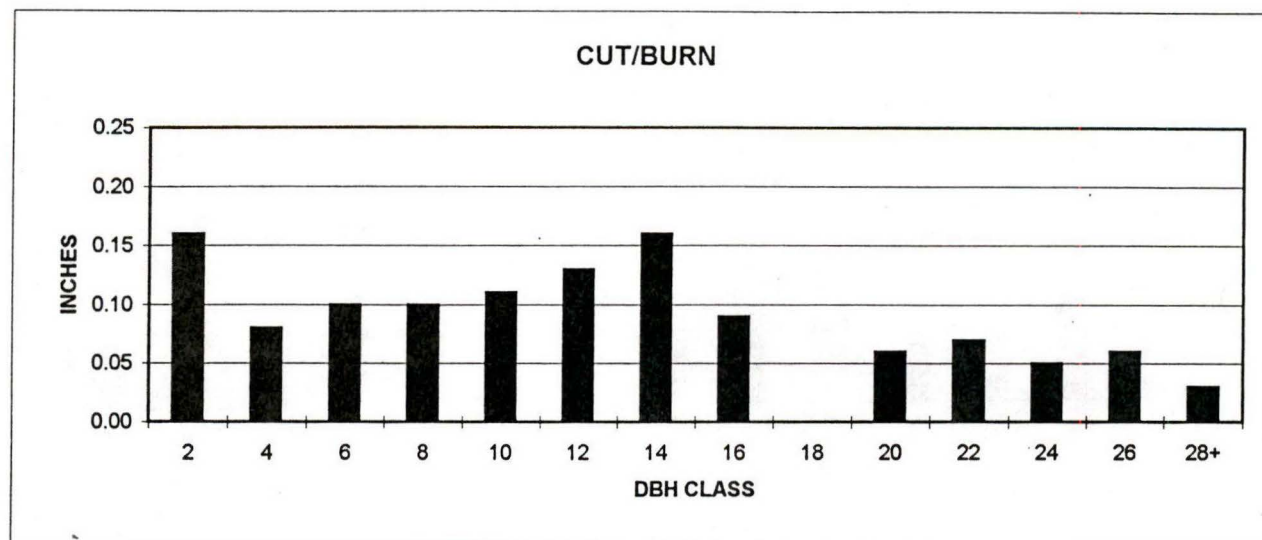


Figure 2. Periodic annual height increment by treatment and diameter class, for the five-year period 1993-1997.

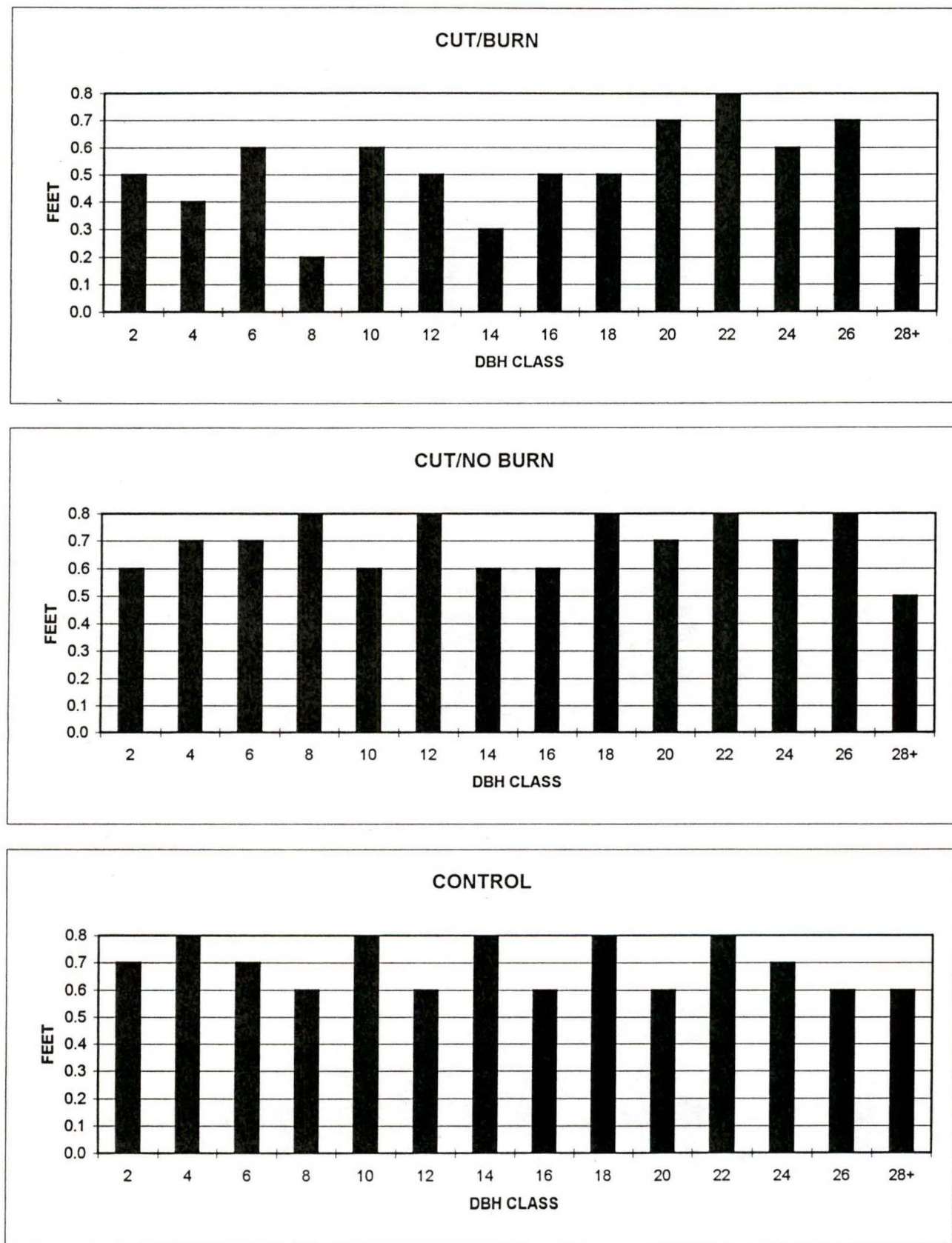


Figure 3. Periodic annual basal area increment per tree, by treatment and diameter class, for the five-year period 1993-1997.

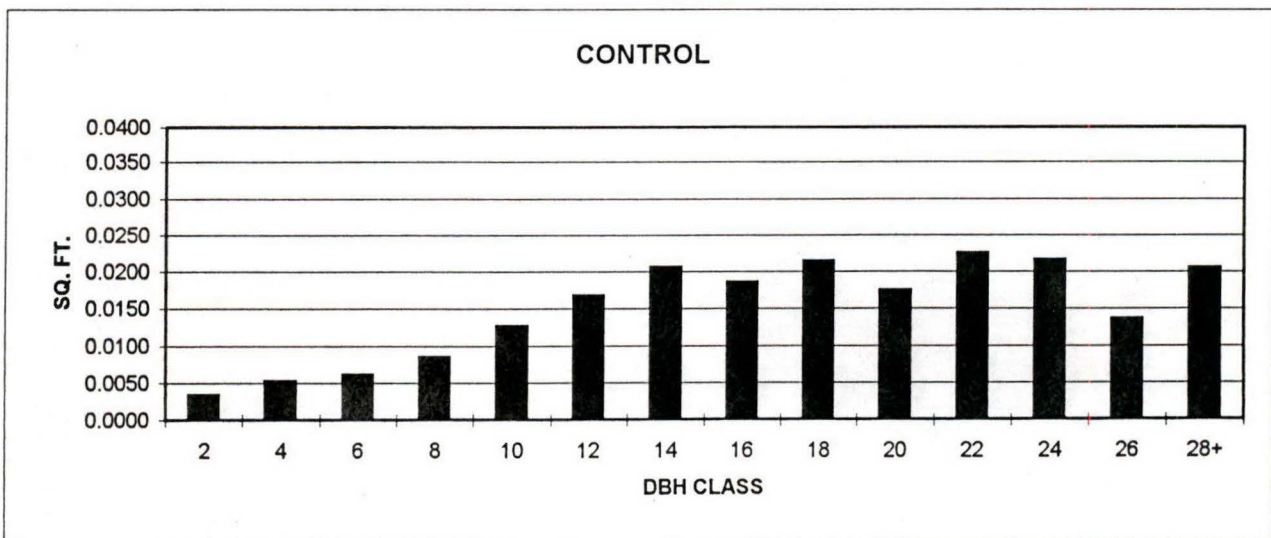
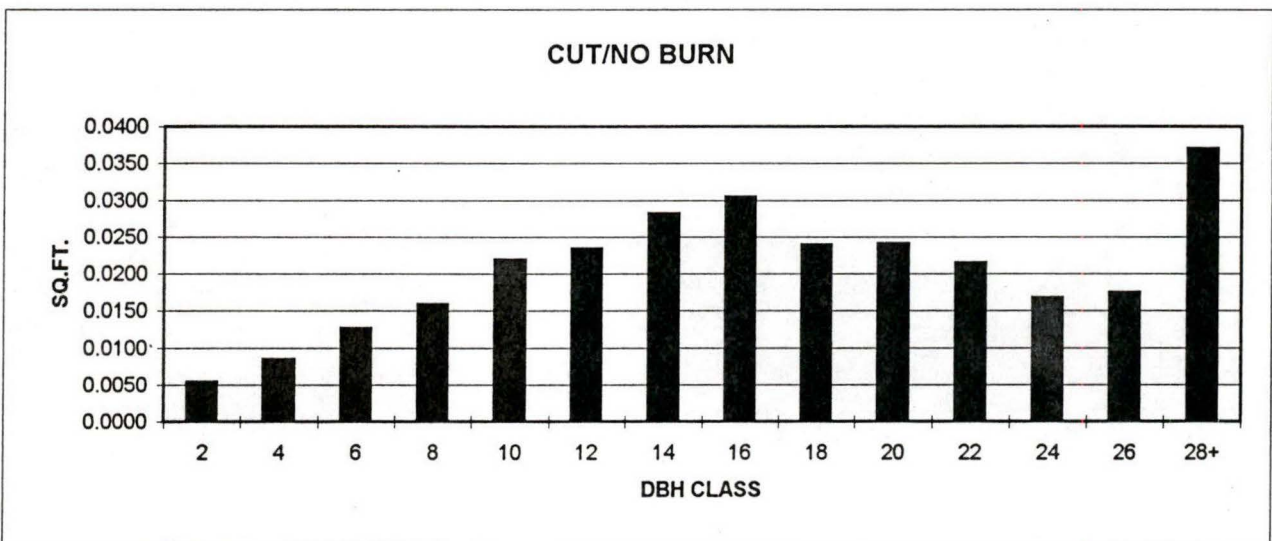
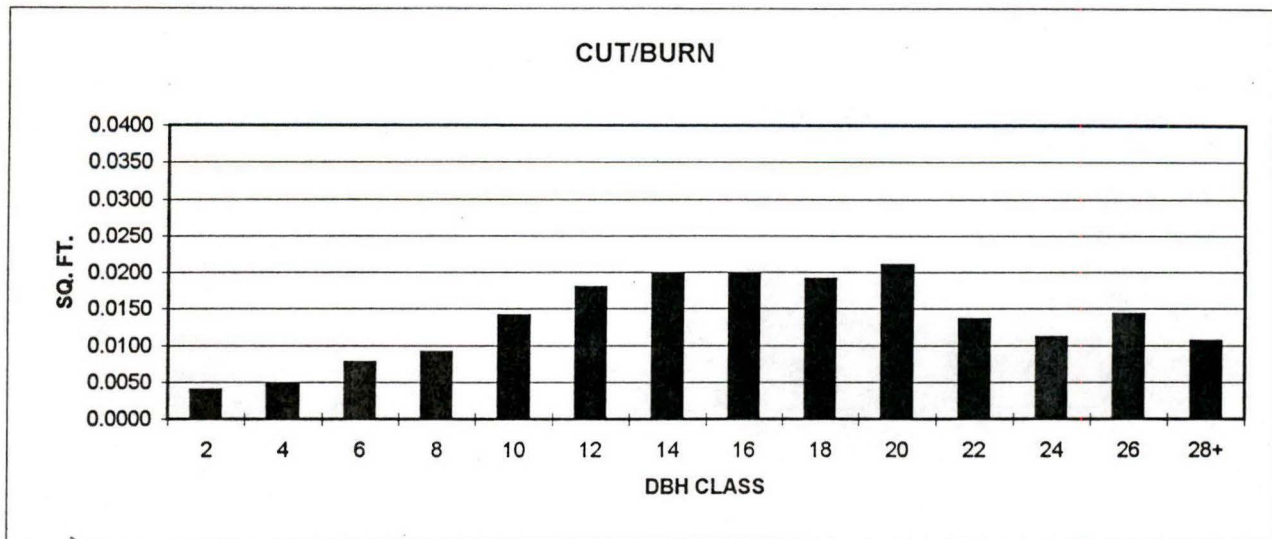


Figure 4. Periodic annual basal area increment per square foot of basal area, by treatment and diameter class, for the five-year period 1993-1997.

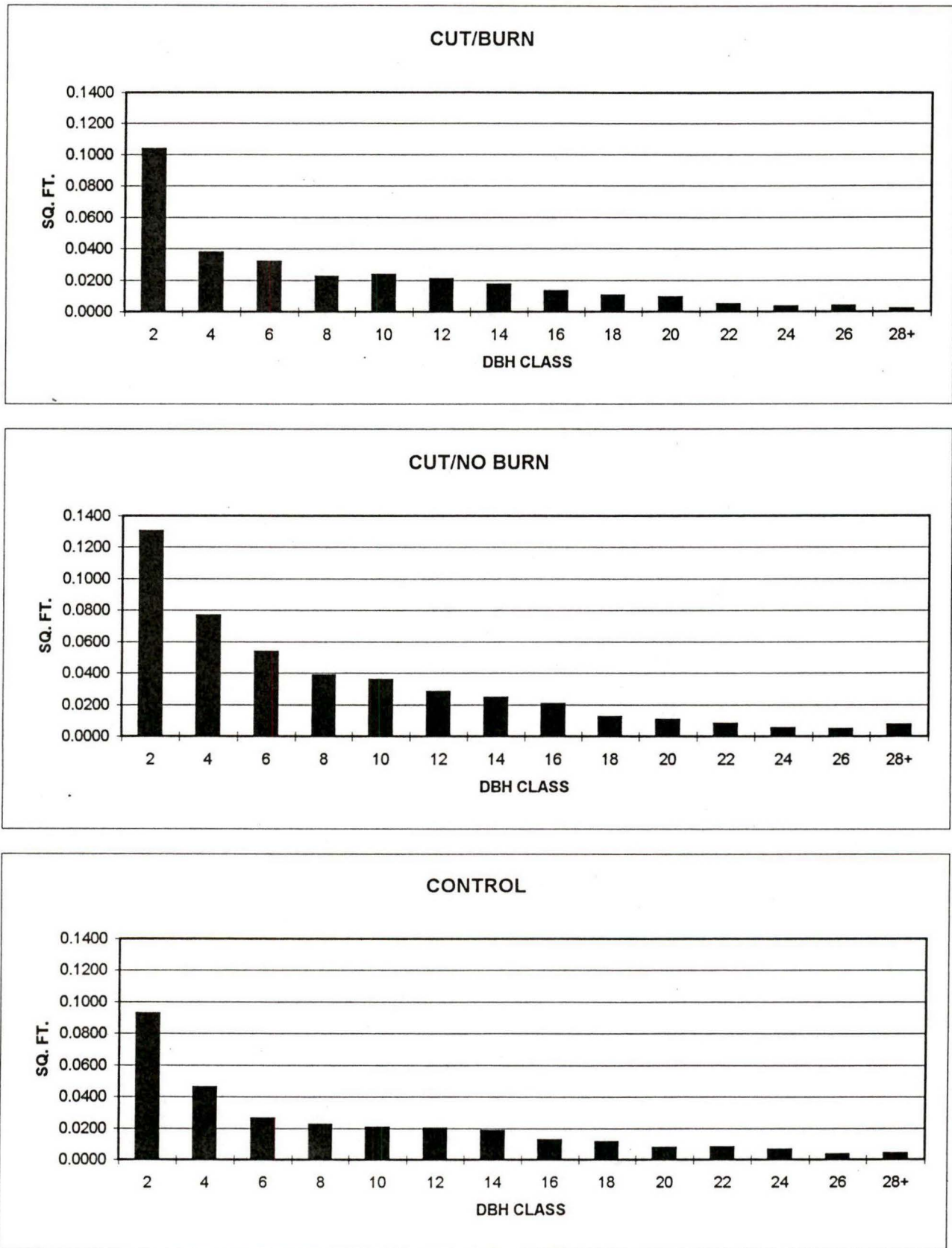


Figure 5. Periodic annual cubic volume increment per tree, by treatment and diameter class, for the five-year period 1993-1997.

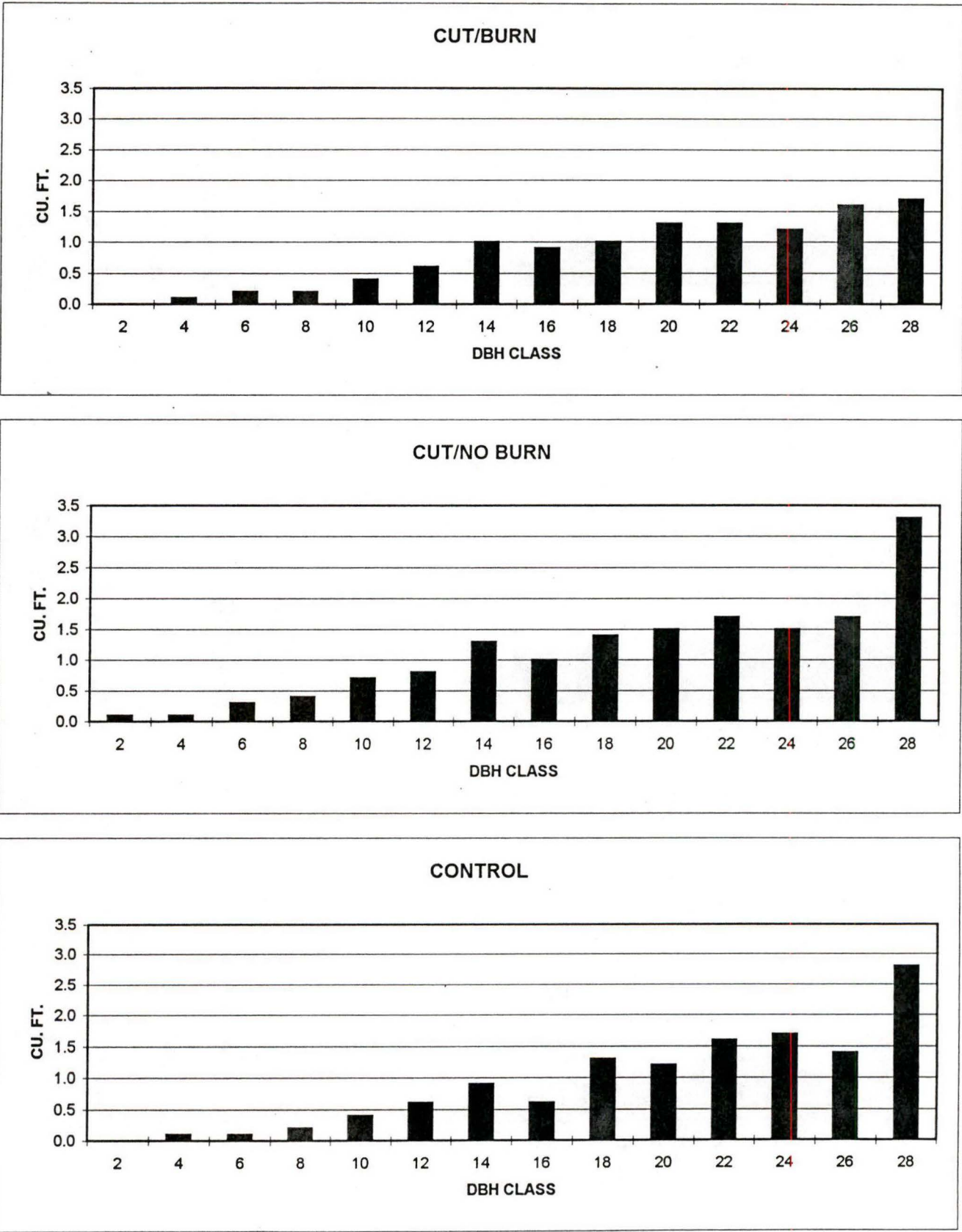


Figure 6. Periodic annual board foot volume increment per tree, by treatment and diameter class, for the five-year period 1993-1997.

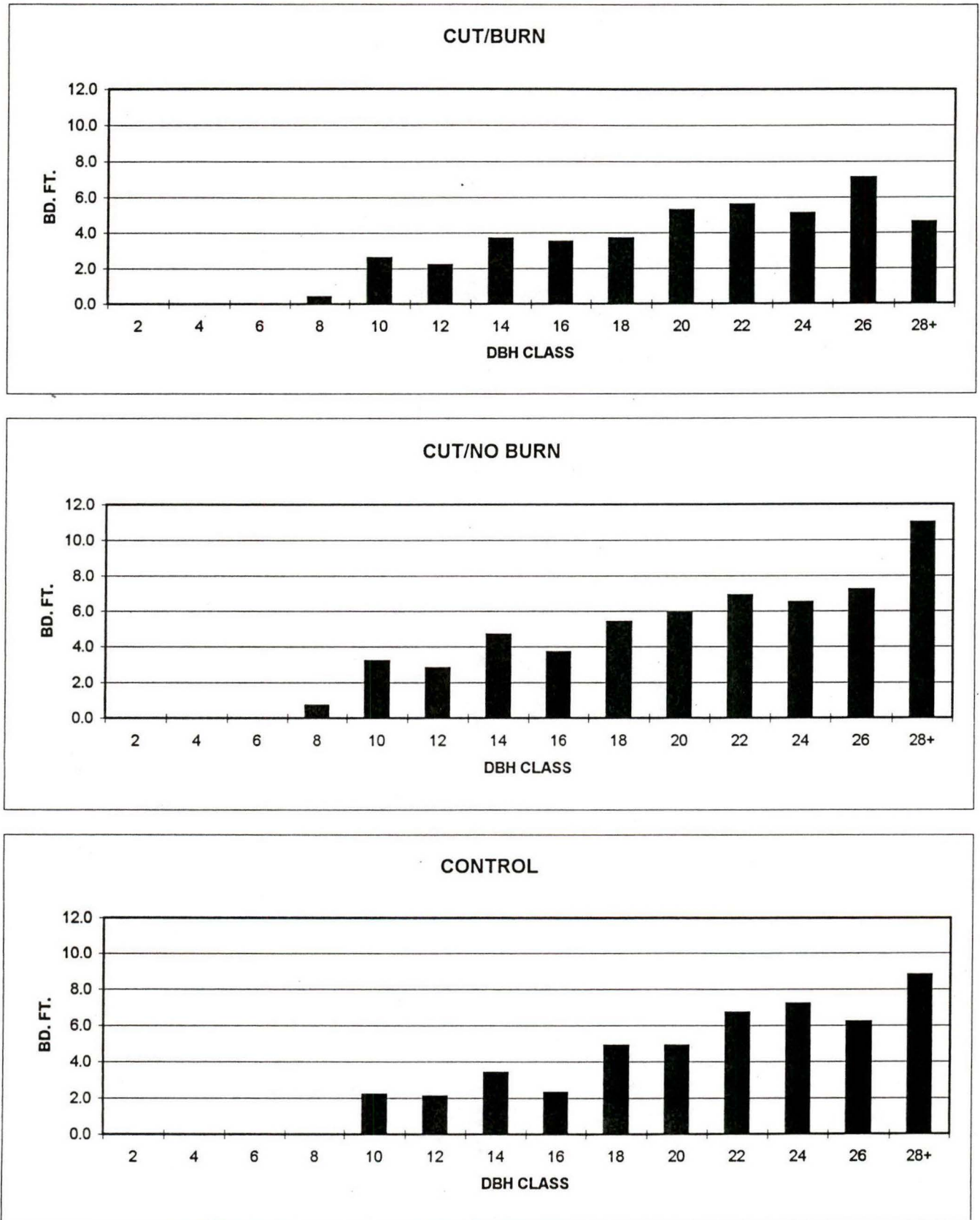


Figure 7. Total mortality (all causes) by treatment and diameter class, for the five-year period 1993-1997.

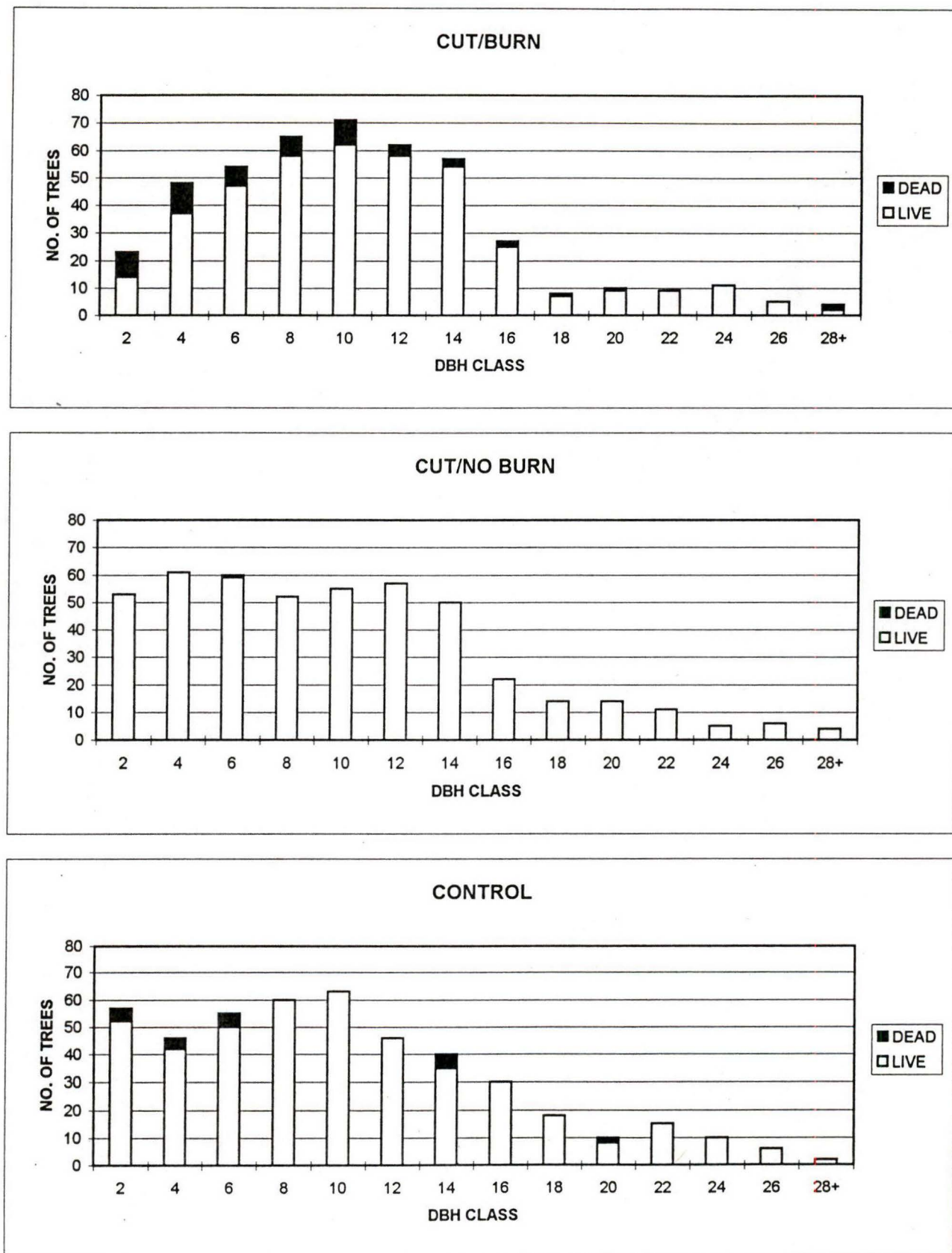


Figure 8. Fire-caused mortality, by diameter class, for the five-year period 1993-1997.

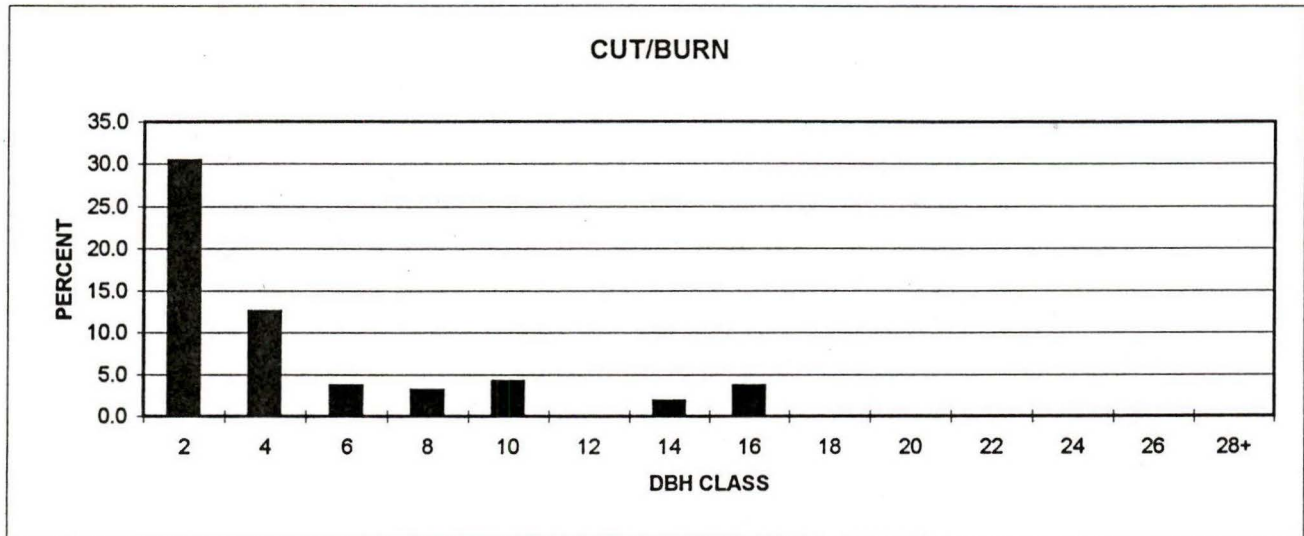


Figure 9. Beetle-caused mortality, by treatment and diameter class, for the five-year period 1993-1997.

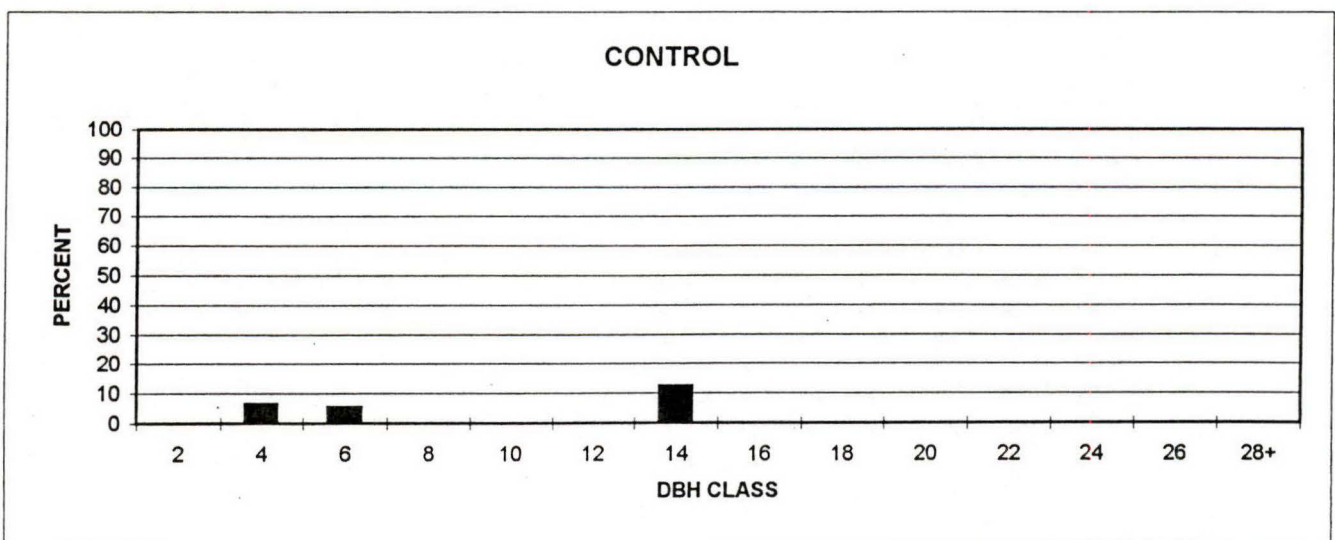
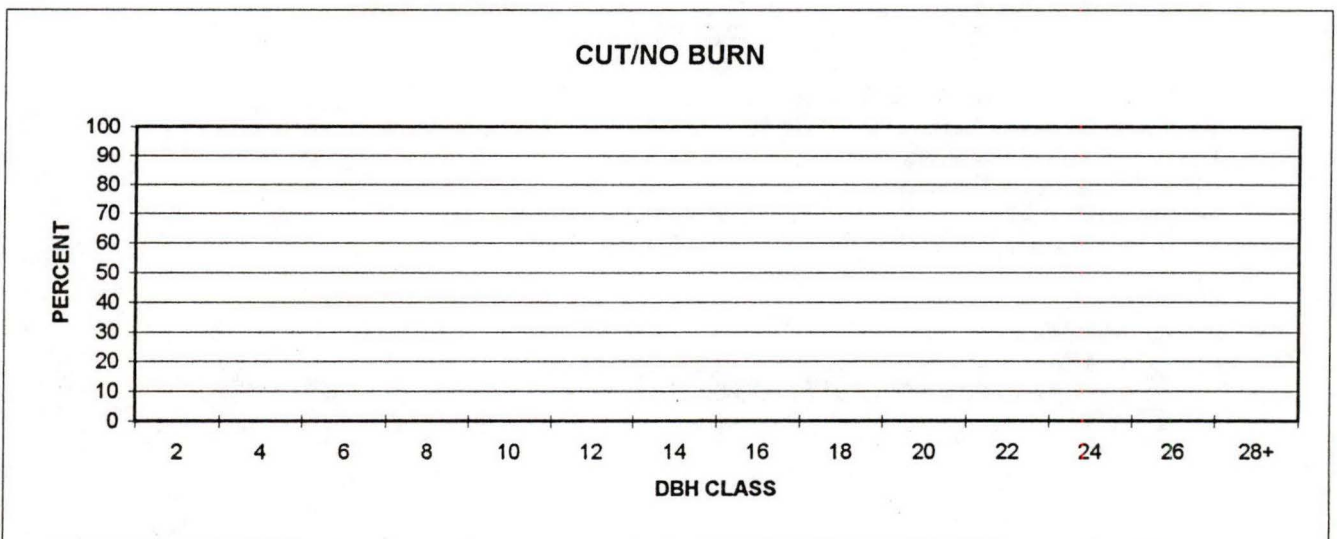
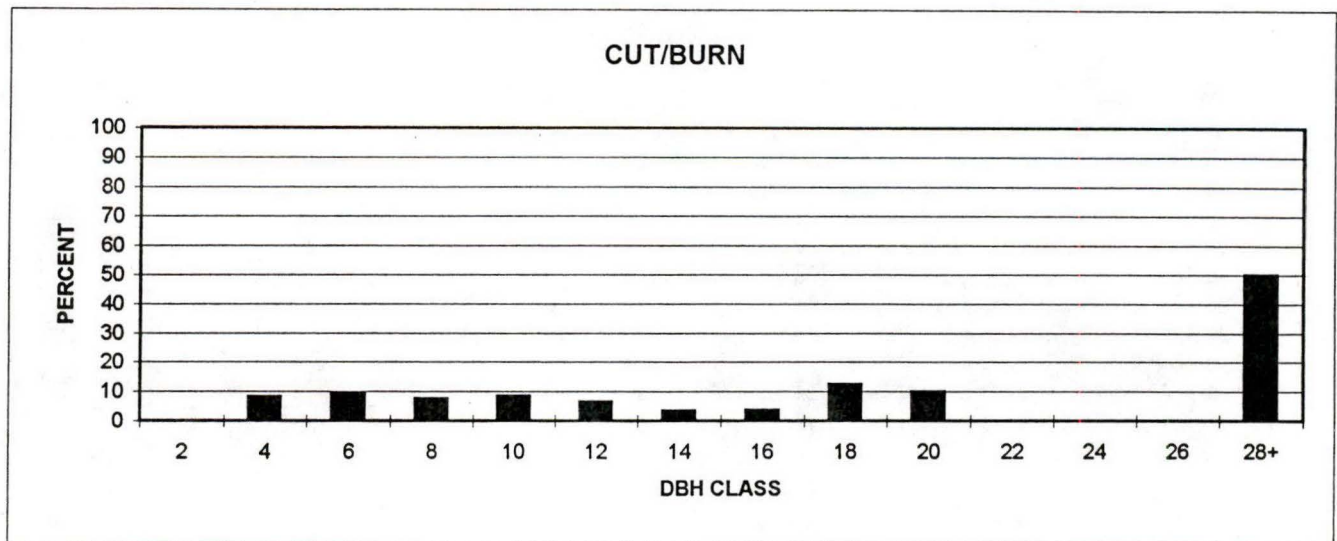


Figure 10. Percent of trees attacked by beetles, by treatment and diameter class, for the five-year period 1993-1997.

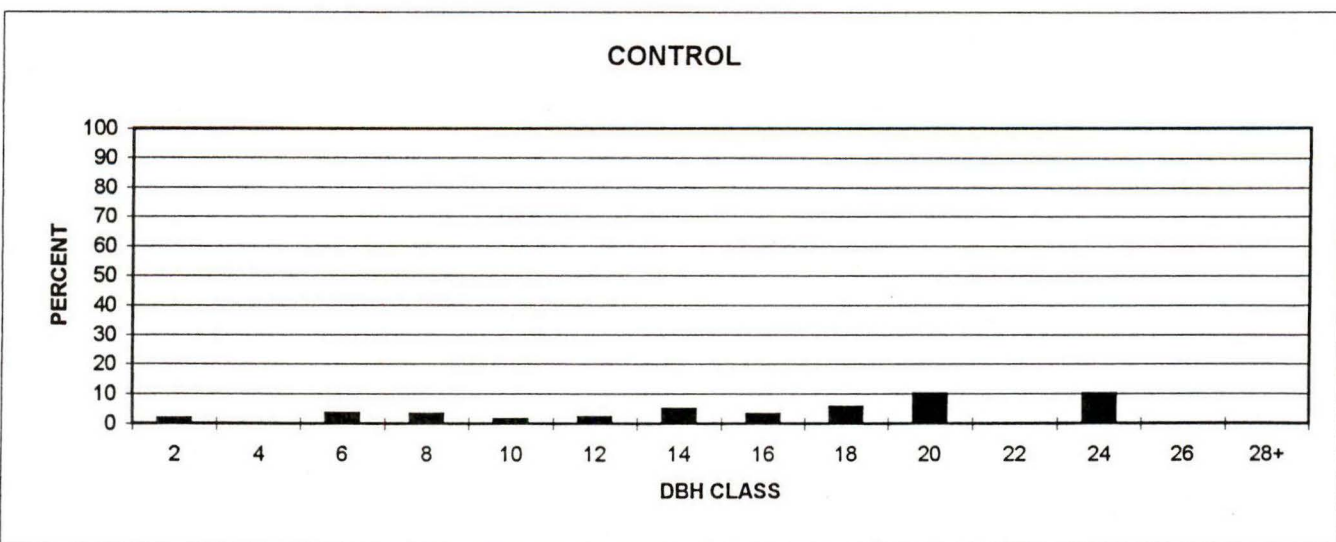
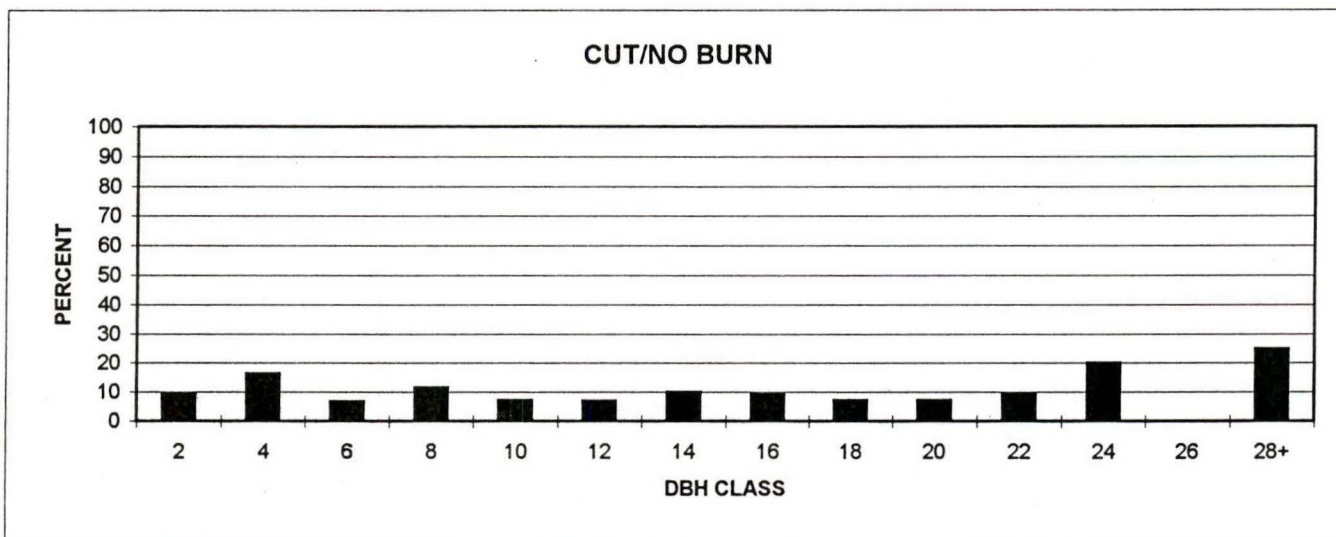
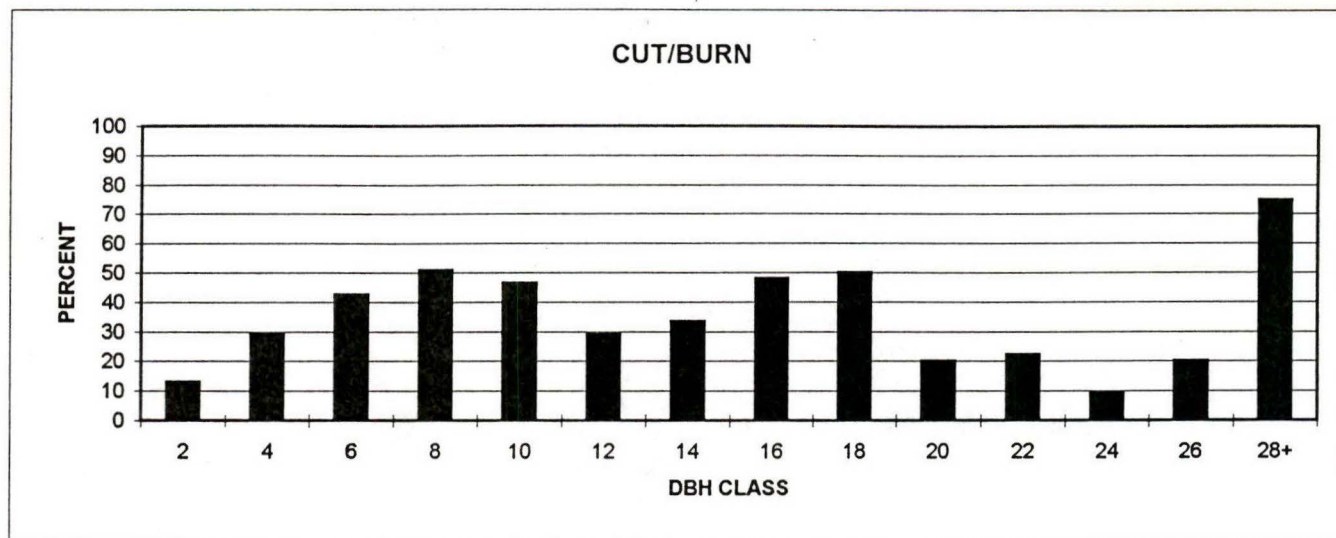


Figure 11. Mortality due to causes other than fire or beetles, by treatment and diameter class, for the five-year period 1993-1997.

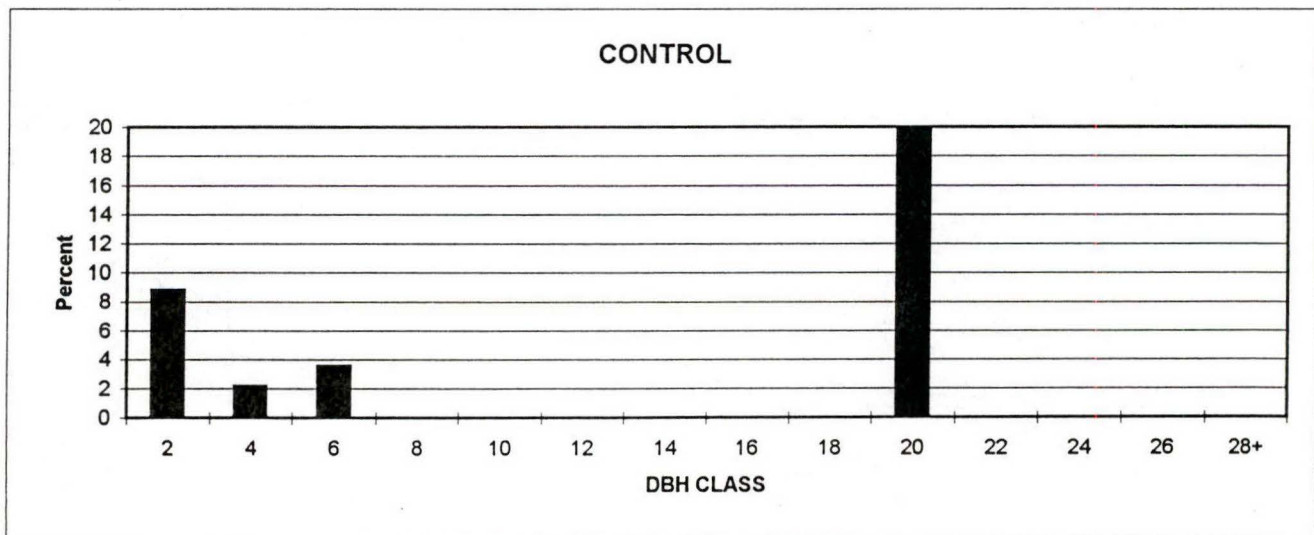
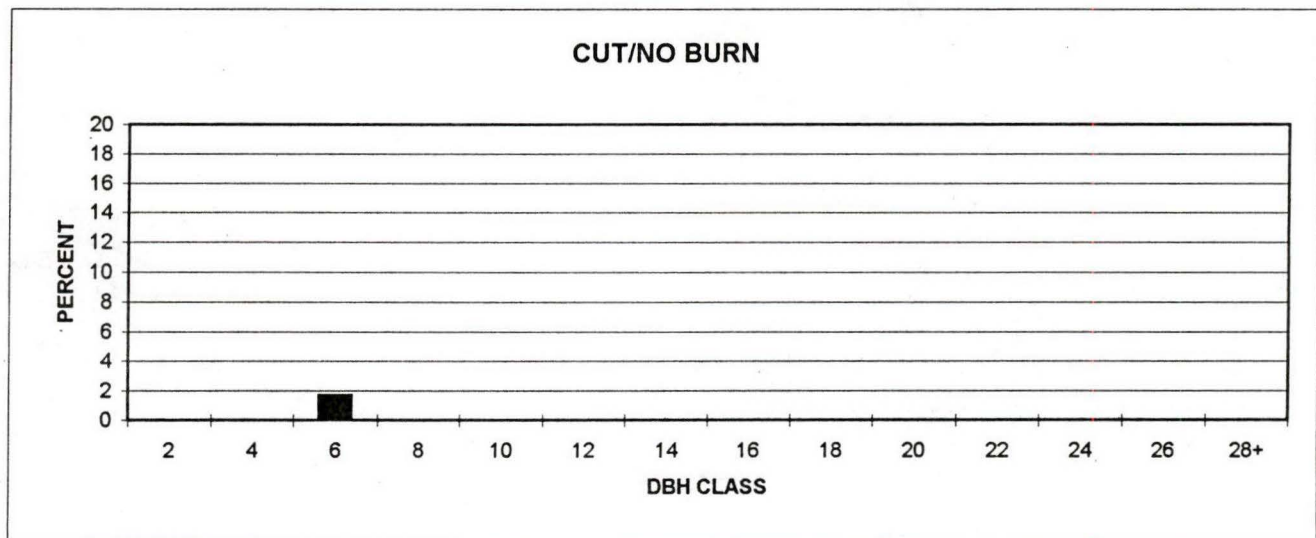
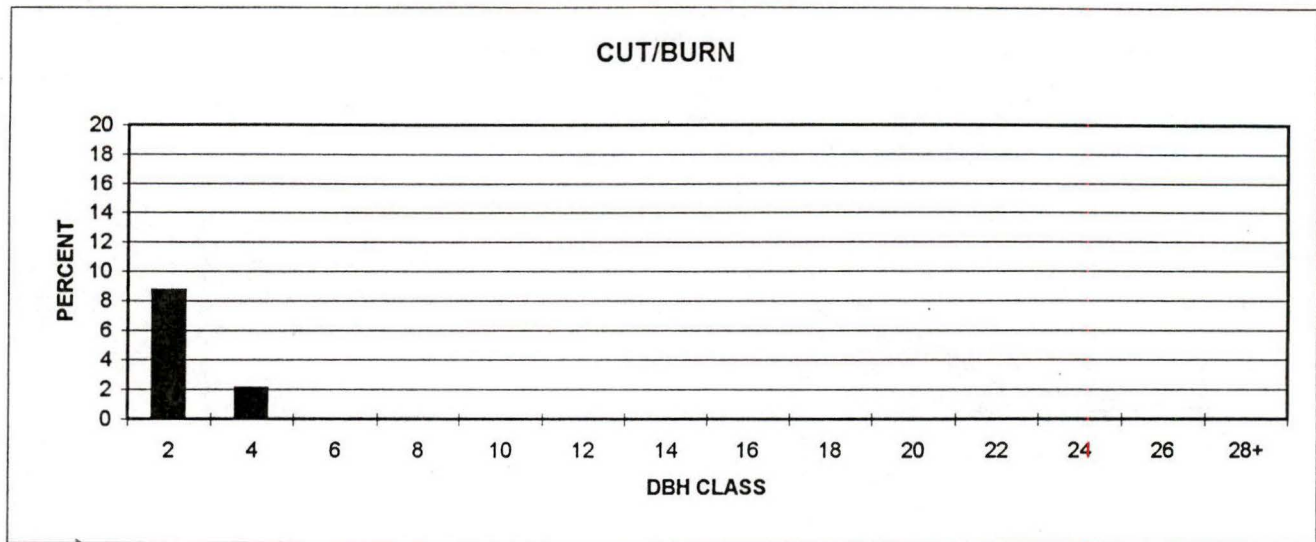


Figure 12. Cumulative annual mortality, by treatment and cause, for the five-year period 1993-1997.

